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The Use of Benthic Macroinvertebrates by Rainbow Trout (Oncorhynchus mykiss) in Lake Ogallala, Nebraska

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THE USE OF BENTHIC MACROINVERTEBRATES

BY RAINBOW TROUT

(*Oncorhynchus mykiss*)

IN LAKE OGALLALA, NEBRASKA

By

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THE USE OF BENTHIC MACROINVERTEBRATES BY RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) IN LAKE OGALLALA, NEBRASKA.

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In Lake Ogallala rainbow trout (*Oncorhynchus mykiss*), which feed on a predominance of macroinvertebrates, are managed as a put, grow, and take fishery. Paired (2.9 m^2) corrals were placed at three sites, to test whether trout were feeding selectively or opportunistically on benthic macroinvertebrates, and to document whether changes in the benthic community are caused by fish feeding. Core samples and invertebrate activity traps were used to evaluate abundance of macroinvertebrates in corrals. Three rainbow trout were placed in one corral at each site allowed to feed for a week, removed, and preserved for stomach contents analysis. Fish stomach contents were compared to core samples, and activity traps using ANOVA procedures and percent index of relative importance (%IRI). The three most important food taxa were Corixids, Chironomids, and Gastropods. No significant relationships were found between %IRI and abundance of benthic macroinvertebrates at the three sites. Based on this I conclude that rainbow trout are feeding opportunistically and are not having a significant effect on the benthos of Lake Ogallala.

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Table of Contents

List of Tables

List of Figures

Introduction

The ability of an aquatic environment to support fish populations is directly related to the abundance of certain aquatic insects (McCafferty 1983). Studies of the interactions of fish and invertebrates are a link in the understanding of aquatic ecosystem function. Fisheries resource research should include not only the study of fish food preferences and feeding habits, but also the study of insect ecology (McCafferty 1983), because interfacing these two fields can lead to a greater understanding of production in freshwater environments.

Interactions between benthic macroinvertebrates and fish have been debated for years, and there are many different studies that have shown conflicting results. Thorp (1986) described what he calls a "…severe split in the ranks of community ecologists between those who believe that predators have a significant role in regulating community structure, and those who have challenged either the universal or relative importance of predators."

Fish Feeding:

Studies have shown that predation by fish decreases the density of benthic macroinvertebrates. Hall et al. (1970) introduced bluegill (*Lepomis macrochirus)* to experimental ponds that previously contained no fish and noted a decreased density of large benthic macroinvertebrates. Morin (1984) placed exclosures in a North Carolina farm pond. Half of them excluded fish, and the other half allowed fish to enter by a hole in one side. He found that the density of small to medium size macroinvertebrate larvae decreased in exclosures where fish were allowed entry.

When one million fingerling cutthroat trout were stocked in previously fishless Lake Lenore in eastern Washington, Luecke (1990) found a decline in density of offshore benthic macroinvertebrates but not in the littoral zone. In contrast, after the introduction and proliferation of yellow perch (*Perca flavescens*) in Little Minnow Lake, Alqonquin Park, Ontario, the density of littoral benthic macroinvertebrates decreased (Post and Cucin 1984). So even within studies that agree that fish predation does decrease densities of benthic macroinvertebrates, there is no consensus on how these densities are reduced.

Studies have also found that the density of benthic macroinvertebrates actually increased with the introduction of vertebrate predators. In one study, the predator was introduced into a pond, and the density of chironomids increased because the density of odonate predators decreased (Crowder and Cooper 1982). Gilinsky (1984) placed predators in enclosures, and this led to an increased density of macroinvertebrates in autumn and winter but no change in spring and summer.

Above are some examples that illustrate how predators have an effect on the density of benthic macroinvertebrates. It appears that fish do impact the density of the benthic community. However, there have been studies that show that vertebrate predators have no effect. Thorp and Bergey (1981) placed exclosures, which excluded fish in Par Pond, South Carolina, and compared those to areas of the same size to which fish had access. Their findings indicated that predators had no significant effect on the density or taxon richness of the benthic macroinvertebrates.

As such, different fish have different affects on the benthic assemblage. Some directly eat the macroinvertebrates, while others eat their predators or competitors, which allows for populations growth. There is a clear relationship between these two groups of organisms and further study into interaction between them can only shed light into the realm of freshwater ecosystem function.

Rainbow Trout Feeding:

Rainbow trout feed on various invertebrates including zooplankton, larger crustaceans, insects, snails and leeches that occur in their habitat (Scott and Crossman 1973). A rainbow trout's diet switches from invertebrates to fish when it reaches around 300 mm in total length (Marrin and Erman 1982). However, in smaller lakes it has been found that rainbow trout fare well on invertebrates alone (Scott and Crossman 1973). Trout take only benthic organisms that are visible, and they do not burrow or root out their prey. This is the reason that they have "little foraging power" on benthic organisms (Gerking 1994). Several studies have shown this to be true in lakes as well as in streams. Swift (1970) found that larval chironomids, which are mostly benthic burrowers, made up 83.8 % of the total benthic energy in Castle Lake. However, the percentage of utilization by trout was only 5.8%. In Nebish Lake, Wisconsin, Brynildson and Kempinger (1973) found that larval chironomids, in most cases, do not make up large portions of trout diets. When a large number of stomachs contain them, they make up a small percentage of what is found in those stomachs. Chironomid pupae made up a larger percentage of the total food items in the stomach. Trout probably fed most heavily on them as they emerged and rose through the water column (Marrin and Erman 1982). These are important factors to consider because the majority of invertebrates in Lake Ogallala are larval chironomids (Laux et al. 1996, Peters et al. 1999, Peters et al. 1998).

While the studies above show that chironomids do not make up an important part of a rainbow trout's diet, others have shown different results. Weiland and Hayward

(1997) found that chironomid pupae were the most important food item for rainbow trout in Lake Taneycomo. An index of relative importance (IRI) was used to rank food taxa. Chironomid pupae were ranked first with an IRI value of 3,251. The next closest taxon was a *Cladocera* spp. with an IRI value of 1,085. The diet of rainbow trout in two montane lakes in the Coast Mountains also was dominated by chironomids (Johnston et al. 1999). The diets of the trout were similar in both lakes, with chironomids making up the largest proportion of items in the stomachs in the spring and fall, and the smallest during summer.

Background

Lake Ogallala was formed by the removal of earth to build Kingsley Dam in 1941 which impounds C. W. McConaughy Reservoir. Lake Ogallala is a 263 ha impoundment with two main basins(Figure 1). The main basin, which runs north and south, has an area of 103 ha with a maximum depth of 12 m and average depth of 7 m. The Keystone pool, which runs east and west, is much shallower with a maximum depth of 4 m and average depth of 1.9 m. Water enters Lake Ogallala through Kingsley Hydroelectric Power Plant. Because the plant's intake is located in Lake McConaughy's hypolimion, the temperature of water that enters the lake rarely exceeds 16°C, which is a suitable temperature for trout all year long. During the later months of the summer, when Lake McConaughy is thermally stratified, the water entering the lake has very low dissolved oxygen and high levels of ammonia. This may contribute to some trout leaving the lake during late summer. The lake has two main exit points controlled by gates, the North Platte River and the CNPPD irrigation canal. Lake Ogallala is managed as a put, grow and take rainbow trout fishery, and it is also the most important cold water fishery in the state.

In the mid-1960's the Lake Ogallala fishery began to decline and was dominated by non-game species. The fishery had degraded to the point where a complete chemical renovation was conducted in October 1969 (Madsen and Eichner 1996). Because of the renovation, Lake Ogallala developed into a quality put, grow and take fishery. This outstanding fishery lasted from 1971 until about 1990 (Madsen and Eichner 1996). At this time, non-game fish populations had risen to a level at which it was assumed they were out-competing the trout for food resources. Studies showed that 78% by number and over 90% by weight of the fish in the lake were non-game species (Laux et al. 1996). The lake was dominated by alewife (*Alosa pseudoharengus*), carp (*Cyprinus carpio*), and white suckers (*Catostomus commersoni*). Alewife are extremely effective filter feeders and devastating predator on zooplankton. They are able to filter down to a vary small size, much smaller then the size that rainbow trout are able to filter out. These fish have a population of great enough number in the lake that they were able to keep the zooplankton population at a level where the zooplanktors were to small to be used (filter out) by the rainbow trout. Without zooplankton of feed on the trout have to feed almost exclusively on benthic macroinvertebrate. This meant that they would have to compete with the carp and white suckers of the lake. The carp and white suckers are better equipped to feed on the benthic population. They also were thought to be responsible for not allowing the aquatic macrophytes to become established, because they kept the bottom disturbed with their feeding. By not allowing macrophytes to establish themselves the carp and suckers limited the invertebrate population to only benthic invertebrates and no epiphytic invertebrates. The lack of epiphytic invertebrates and competition from carp and suckers for benthic invertebrates lead to a decline in trout health. The average size of the harvested trout decreased from 290 mm to 269 mm, with a corresponding decrease in weight from 315 g to 198 g. (Madsen and Eichner 1996).

In order to improve the fishery, the Nebraska Game and Parks Commission chemically renovated Lake Ogallala in October 1997. This was done to remove non-game fish such as carp, white suckers, and alewife, which were competing for food with trout. . It is also important to realize that because Lake Ogallala receives its water from Lake McConaughy, alewife have already reentered the lake. It was expected that stocked trout would grow bigger and stay in the lake longer. The removal of these non-game fish allows us to determine whether the high number of trout leaving the system and low angler success was due to competition for food or some other factor which had gone undetected The removal of the carp and white suckers allowed the invertebrates to reestablish themselves to a point at which they will become a good food source for trout. The alewife will most likely not allow the quality of zooplankton to improve to a point where it is a good source of food for the trout.

A study of the lake by the University of Nebraska-Lincoln has been on going since the summer of 1994 (Laux et al. 1996) and will continue throught the summer of 2000. This study characterizes the fish, benthic, and zooplankton communities of the lake. It established eight permanent sampling sites, which were sampled monthly for fish using frame and gill nets, and electro-fishing . Water quality sampling, which included benthos, zooplankton, water temperature, dissolved oxygen, and phytoplankton sampling, was done at each site bi-monthly. This sampling was done at three stations (inner, middle and outer) at each site. From these samples the health of the system was able to be determined. This study is responsible for much on the above information on the lake.

Lake Ogallala presents a unique opportunity for studies of fish feeding biology. By allowing us to examine the feeding ecology of rainbow trout without many competitors, and to see how this feeding changes when the competitors become more abundant. The Lake Ogallala study is focused on the fish and invertebrate populations before and after chemical removal of the fish population in October 1997. This thesis investigates how stocked rainbow trout use benthic macroinvertebrates.

My objectives where:

1.) To determine changes in the invertebrate assemblage during the summer with and without predation.

2.) To determine if trout are feeding selectively or opportunistically on the macroinvertebrates.

Methods

Field Work:

To test for relationships between rainbow trout and benthic macroinvertebrates in Lake Ogallala, six limno corrals isolating 2.9 m^2 of substrate were constructed. A portion of the corrals confined trout to a known area, thereby controlling the area where they were allowed to feed. The remaining corrals excluded all fish feeding from a known area of substrate.

Corrals were constructed of PVC pipe, flexible irrigation pipe, chicken wire, and poly tarp. The top and bottoms rings were made out of a 6 m piece of 3.75 cm flexible irrigation pipe. This pipe was cut into four 1.52 m sections and connected using 4.38 cm PVC t-fittings. Vertical supports were 1.67 m pieces of 4.38 cm PVC pipe. All connections were screwed together. This skeleton was then wrapped in 1.875 cm mesh chicken wire, and fastened with plastic zip ties. To ensure that the corrals fit tight to the substrate of the lake, and prevent entry or exit of trout a skirt of poly tarp was added to the bottom. This skirt was a 6.63 m by 45 cm piece of tarp, with a pocket folded in the bottom to hold a chain, and grommets spaced every 0.3 m to allow it to be attached to the corral. The skirt was attached to the corral by zip ties15 cm up on the chicken wire; this left 30 cm of tarp to hang straight down

Two corrals were placed at each of three study sites that represented the main types of littoral habitat available to rainbow trout in Lake Ogallala. In addition, these sites were also adjacent to sites that were sampled every other week for water quality and macroinvertebrates. After the corrals were positioned in the lake, they were to fence posts driven into the substrate. The tightness of the seal to the bottom was visually checked by snorkeling.

All corrals were placed in the lake during, June in 1998 and May in1999 and were not moved until they were removed at end of the study period (September 1998, and August 1999). Corrals excluding fish were sampled for benthic invertebrates every other week in 1998 (June-September) and every week in 1999 (May-August) using a hand corer. The corrals which received fish were placed in the same area as the corral without fish. These corrals were sampled for invertebrates before fish were introduced and then again a week later after the fish were removed. Each corral received three 200-300 mm rainbow trout collected from the lake using a pulsed D.C. electrofishing boat. This size class was chosen for two reasons. First, it is the length at which the trout are initially stocked (Madsen and Eichner 1996). Second, and more importantly, at this size they are not yet piscivorous (Jude et al. 1987) and totally dependent on the benthic macroinvertebrates because of the lack of available zooplankton in the lake.

Before the trout were placed into the corral, they were held for twenty-four hours in a floating pen in the lake to ensure that they survived the collection process. Each fish was measured (TL), weighed, and randomly assigned to a corral. After a week, the fish were removed by electrofishing early in the morning and preserved in 10% formalin solution. Since trout feed actively at dusk and dawn, morning removal of the fish gave the best chance for finding full stomachs (Willers 1981). In addition, lake levels were lowest in the morning, which facilitated fish capture. The corrals that had contained fish were then moved a short distance along the shoreline and reset. This process was repeated eight times each summer.

All invertebrate samples were collected with a 5.08 cm diameter corer. Two cores were taken per corral to sample the benthos before being preserved the cores were rinsed together in a wash bucket. These samples were preserved in 10% formalin, and taken back to the lab for analysis. In 1999, activity traps were used to sample mid-water invertebrates, because it was found that this was a food resource not being adequately sampled. These activity traps were fashioned using 2 L plastic soda bottles after the design developed by Murkin et al. (1983) and used by Gordon et al. (1990). A trap was placed on the side of each experimental enclosure for twenty-four hours before the end of each experimental run and removed and emptied the next morning.

Lab Work:

All core samples were floated using a salt solution to facilitate manual sorting. Invertebrates were identified using keys from Merritt and Cummins (1996), McCafferty (1983), Pennak (1989), and Huggins et al. (1981). Chironomidae were identified to genus using the key of Coffman and Ferrington (1996). Chironomid heads were mounted on glass slides using CMC-10. Two heads were mounted per slide, with a single head under a cover slip.

Fish stomachs were removed and the contents were identified to the same taxonomic level as the core samples. The larval chironomids were sorted into four different size classes, X-large, large, medium, and small, and the number in each class was counted. This was done only to increase the precision of the measurements that were derived from later stomach analysis.

To determine dry weight of the macroinvertebrates in the sample, a set of standard weights was established. Ten to fifteen individuals of each taxon were used to determine the standard weight for that taxon. As eluded to early the larval chironomids were divide into four size classes. These four classes were easily discernable from each other, and did not require measurement. These individual size class weights increase the precision of the weights taken from the stomach contents.

After the groups were sorted the dry weights were taken following the procedure used by Popp and Hoagland (1995). A piece of 70 mm Whatman filter paper was rinsed in distilled water and then allowed to dry for 24 hours at 70°C. It was then removed and allowed to cool to room temperature in a desiccator. The filter paper was weighed to the nearest 0.1 mg and then placed back in the desiccator and reweighed until no difference was found. Next, ten to fifteen individuals of the same taxon were place on the paper and dried again at 70°C for 24 hours. The filter paper was then removed, allowed to cool to room temperature in a desiccator, and weighed again to the nearest 0. 1 m g. This paper was reweighed until no difference was found. The difference between the filter paper with insects and the filter paper without insects gave the total weight of the insects on the paper. This was then averaged to get the average weight of an individual of that size group and taxon. All the major food taxa were weighed in this manner.

Three measurements were used to characterize stomach contents, frequency of occurrence ($\%O_i$), percent by weight ($\%W_i$), and percent by number ($\%N_i$) of total food items. These three measures were combined to form an index call the index of relative importance (IRI) (Hyslop 1980). Where IRI is:

$$(\%O_i*(\%W_i+\%N_i))$$

This index seems to cancel out the biases of its individual parts (Bigg and Perez 1985). Because the IRI values are not expressed in a percentage form, they are hard to compare between studies, so Cortes (1997) suggested that they should be expressed on a percentage basis. This yields the formula:

$$\%IRI_i=100*IRI_i/\Sigma\ IRI_i$$

The output of this formula gives you a set of numbers that add up to 100. Each number represents how important that food item is to the fish, and the item with the largest number is the most important. This facilitates interpretations and comparisons. To assure that all taxa are given the same weight, the same taxonomic level was used for each group and the individual life stages (larval, pupae, and adult) were not broken up.

Analysis was performed on the data using ANOVA procedures to look for difference between control vs experimental benthos, control and experimental vs lake benthos. Since replication for these test occurred through time during the summer of 1998 and 1999 I calculated regression of numbers of each major taxon for the control and experimental corrals. This was done to determine whether changes through the summer were consistent in both experimental and control corrals. ANOVA procedures were also used to look at %IRI at different years, and %IRI in the same year at different sites. In order to determine if relationships existed between %IRI and abundance of the benthos, these were compared using linear regression.

Results

Objective 1:

Core samples showed that at all sites in 1998 and 1999 chironomids were the most abundant benthic food taxon available (numbers/cm^2), both weekly and throughout the summer in the experimental corrals (Tables 1 and 2). In 1998 and 1999 gastropods were the second most abundant benthic food taxon at all experimental sites (Table 1 and 2). Oligochaetes were found in higher numbers/cm^2, but are not considered a food taxon. Weekly totals of the three food taxa are also presented in Tables 1 and 2. The number of corixids collected in both years is displayed in Table 3. Because activity traps were used to sample corixids in 1999 but not in 1998, an ANOVA procedure (α=0.05) was used to test for significant differences between the numbers of corixids captured between years at each site (Table 4). The ANOVA procedure showed no significant differences in number of corixids between years, sampled without using activity traps. The taxon with the fewest representatives were corixids and gastropods in 1998 and 1999 respectively (Tables 1 and 2). The most abundant taxon from the control corrals was chironomids at all but site 2 in 1998 (Table 5 and 6), where oligochaetes were most numerous (Table 5).

The genera of chironomids found in core samples taken in the experimental and control corrals and from trout stomachs are listed on Tables 7 and 8. *Dicrotendipes*, *Chironomus*, and *Polyedilum* were found in both years. The rank for each genus from the experimental, control, and stomach samples from each site is found in Table 9. The most abundant genus at site 1 in both years was *Chironomus*. *Dicrotendipes* was the most abundant genus at site 2 in both years. The most abundant genus at site 3 in 1998 was *Stictochironomus* and *Dicrotendipes* in 1999. For the whole year in 1998 the two most abundant genera were *Chironomus* and *Dicrotendipes*, and in 1999 the two most abundant genera were *Dicrotendipes* and *Cryptochironomus*.

Regressions of major benthic taxa abundance in control and experimental corrals showed no statistically significant differences throught the summer. Therefore I used temporal replication in ANOVA test. Table 10 refers to ANOVA procedures used to compare the three main food taxa in the experimental corrals versus the control corrals. No significant differences were found in these comparisons. Table 11 shows the p-values for the ANOVA comparisons between the control or experimental corrals benthic samples and benthic samples taken from the lake. Significant differences were found in five of the 36 comparisons. Three of these show differences between oligochaetes in experimental corrals and those in the lake. These differences occurred at sites 2 and 3 in 1998, and at site 2 in 1999. The two other significant differences between the lake and experimental corrals were between chironomids in experimental corrals at site 3 in 1998 and site 2 in 1999. Therefore, the benthos in the experimental, control corrals, and the lake were very similar so comparisons could be made between them.

Objective 2:

I analyzed 131 rainbow trout stomachs from 54 experimental corral sets over two years (Table 12). In 1998, corixids were the most abundant food item (N=1653) in trout stomachs, followed by chironomids (N=1007), and gastropods (N=52) (Table 10). In

1999, chironomids were the most abundant food item (N=843), corixids were second (N=308), followed by gastropods (N=95) (Table 4).

Weekly percent IRI values of rainbow trout stomach by site are displayed in Figures 2-4 for 1998 and Figures 5-7 for 1999. Site 1 in 1998 had eight runs from which stomach samples were obtained, and one run from which no fish were recaptured (Figure 2). During these eight runs corixids dominated for all but four weeks (%IRI > 55), and where corixids were not dominant, chironomids were the most important taxon (%IRI ≥ 50). Gastropods never had a %IRI greater than 30.

Stomach samples were analyzed for all nine experimental runs at site 2 in 1998 (Figure 3). Corixids dominated %IRI for all but one week (%IRI >63), when chironomids most important (%IRI=91). Gastropods never had %IRI values greater than 17.

At Site 3 in 1998, eight of the nine experimental runs had trout stomachs analyzed (Figure 4). In the first week no fish were recovered. Chironomids were the most important taxon during four of the weeks (%IRI >65). During the week of 7/15/98, chironomids %IRI was 39 while corixids %IRI was 61. During the other three weeks corixids dominated with %IRI near 100.

Stomachs were analyzed from all nine experimental runs from site 1 in 1999 (Figure 5). Corixids were the dominant food taxon in four of the nine weeks, with a %IRI of more than 50. Three weeks were dominated by chironomids while, gastropods were the dominant taxon in two weeks.

Eight of the nine experimental runs at site 2 in 1999 had stomachs analyzed(Figure 6). During the week of 7/1/99 no fish were recovered. Chironomids were the dominant taxon in five with and %IRI ranging from 50 to 100. Gastropods were the dominant taxon in two weeks, and had a %IRI greater than 45 in another week. Corixids were the dominant taxon for only one week (%IRI >83), and were a minor component of food eaten during the rest of the experiments.

Eight of the nine experimental runs at site 3 in 1999 were analyzed for stomach contents (Figure 7). During the week of 8/11/99 no stomachs were analyzed because two of the three fish were dead in the corral, and the third had nothing in it's stomach. Corixids were the dominant taxon for six of the eight weeks. Chironomids had a %IRI of 99 during on 7/28/99, gastropods %IRI was greater than 50 during the week of 8/4/99, but did not appear in any other week. Chironomids were present for all but one week, and when they were present their %IRI was always greater than 18.

Figure 8 is the total %IRI for each taxon during both years of the study. between 1998 and 1999, fish stomach contents at site 1 were very similar in importance of the taxa, when corixids were the dominant taxa followed by chironomids in both years. This was also true for fish feeding at site 3 in 1998 and 1999, where chironomids were the most important taxa in both years. However at site 2, food habits were completely different between years. In 1998 corixids were the most important food item, while in 1999 chironomids were dominant.

To facilitate comparisons, I used the rainbow trout food habits information collected from the lake and expressed them as %IRI values. These values are presented with the %IRI information from rainbow trout collected from corrals at the corresponding experimental sites, to facilitate later comparisons (Figures 9- 11). Food habits comparison for site 1 is displayed in Figure 9. The %IRI values for gastropods, chironomids, and corixids at site 1 in 1998 were 27.4, 46.3, and 26.3, , respectively. In 1999 the %IRI values for gastropods, chironomids, and corixids were 12.6, 23.9, and 63.4, respectively. Figure 10 shows the %IRI number for the lake at site 2 for both years. Chironomids were the most important food item for rainbow trout in the lake during 1998 and 1999. At site 3 the most important food item from the lake in both years was chironomids (Figure 11).

The %IRI from the lake as compared to the corrals in 1998 was different at site 1 and 2, but very close to the same at site 3. At site 1 the corixids had an %IRI value of 60.7 and 26.3 for the corrals and the lake, respectively. In 1999 the %IRI values for corixids at site 1 were 63.4 and 67.6.

Results from ANOVA procedures used to compare %IRI values between all three sites for a single year are found in Table 13. At α=0.05, no significant differences were found in 1998 or 1999. Therefore, the differences in importance of the food items between sites was not significant. In other words, the importance of the food items to the trout were the same throughout the lake. P-values for ANOVA comparisons between %IRI for the three major food taxa between years are displayed in Table 14. The only significant difference was between corixids at site 2 (p-value=0.0001). The remainder of the differences were not statistically significant. In other words, at site 1 and 3 the use of food items was constant during both years, and at site 2 corixids were less important in 1999 than in 1998.

Results from the linear regression used to compare the %IRI versus the abundance on the food item in the benthos are found in Table 15. The best r^2 value found was for corixids at site 3 in 1999 (r^2=0.5479). None of the regression coefficients (a) explained a significant amount of the variation. It appears that rainbow trout are not feeding selectively.

Discussion

Objectives 1:

It is apparent that there was not much difference in chironomid genera between experimental and control corrals. The dominant genus in the control corrals was the dominant genus in the experimental corrals and in the stomachs from those fishes at those corrals in all but three cases. In one of these cases, site 2 in 1998, the same genus was dominant in the stomach and the experimental corral, but not in the control corral. In the other two cases, site 3 in 1998, and site 1 in 1999, the two same genera were dominant in both the control and experimental corrals, but not in the stomachs. The differences here are most likely due to the small number of chironomids squashed in the stomach analysis. Descriptions of the habitats, habits, trophic relationships, and North American distribution of Chironomidae were prepared by Berg et al. (1996) (Table 16). Of the six genera found, five typically inhabit lentic systems. *Stictochironomus* was the only genus that is typically found in lotic systems and it was found most predominately at site 3, which is the area in the lake that has many characteristics of a lotic environment. Use of chironomid larvae by trout did not seem to be affected by their position in the substrate. All genera but Polypedilum, which is associated with vascular hydrophytes, are burrowers.

Since genera did not differ between the experimental and control corrals, and there was not a significant difference between numbers of individuals in the experimental and control corrals (Table 13), this leads me to conclude that rainbow trout in the experimental corrals were not affecting the benthic community.

The benthic community did not differ between the control and experimental corrals for the major food taxa. In most cases, the chironomids were the most abundant taxon, and this was constant for both experimental and control corrals. The oligochaetes in the benthos samples for the experimental corrals (Table 5) at sites 2 and 3 in 1998 appear to be missing. This seems odd. When checked against the samples taken from the lake during the same time period (Peters et al. 1998) oligochaete numbers were also low at these sites. Their absence in the cores samples could reflect their low numbers in the benthos or it could have contributed to a mistake in the sample sorting and identification process. However, oligochaetes did not play an important role as a food source for rainbow trout. In fact, a total of 29 were eaten over two years, and none were eaten at sites 2 and 3 in 1998. It is doubtful that rainbow trout in any way affected the number of oligochaetes in the benthos of the experimental corrals.

The benthic communities in both years and in both types of corrals show similar patterns with the chironomids being the most abundant and their numbers increased all the way through the sampling season until the last sampling in August when numbers typically declined. As stated above, this was the same for both experimental and control corrals. As a whole, 1998 was a numerically more productive year than 1999 for both the experimental and control corrals for all taxa except corixids. The increase in corixids was due to the use of activity traps, which are more suited for effectively sampling. As expected, a gradient of abundance of individuals was found, with the fewest numbers being at site 1 and the most being collected at site 3. This was true for both years, and Laux et al. (1996), Peters et al. (1997), and Peters et al. (1998) found this same trend.

The benthic community was unaffected by fish feeding pressure throughout the summer. No difference was found between the control corrals and the experimental corral for the three main food items found in the trout stomachs. In addition, my results show that there was one significant difference between the lake and the control corrals. This significant difference occurred with chironomids at site 1 in 1998. At sites 2 and 3 in 1998, the fish community of the lake appeared to have no significant effect on the benthic community. The significant difference at site 1 could have several possible reasons. The low abundance of individuals and their tendency to have a clumped distribution may be a reason. Finally, the fish could been having a significant effect on the benthic community in that section of the lake. I would tend to believe that with the low number of individuals available in that section of the lake, the impact of a small amount of fish predation may be easier to detect. The control and the lake were not significantly different in 1999. This data leads to the conclusion that the fish community in the lake did not have any affect on the benthic community of the lake in 1999 and 1999.

Objective 2:

The rainbow trout in Lake Ogallala used benthic macroinvertebrates as their main food source (Peters et al. 1997 and Peters et al. 1998). The main taxa used were the chironomids (larvae and pupae), with the second most abundant being corixids. The reason that the insects were the main source of food and not the zooplankton is because the alewife population in the lake kept the zooplankton size down at a level where in was not usable by the trout.

It appears that in many lakes the preferred food of rainbow trout is zooplankton (Hubert et al. 1994, Johnston et al. 1999, Marrin and Erman 1982, Beauchamp 1990, and McMullin 1979). Other studies, besides those done on Lake Ogallala, have shown that benthos can comprise an important part of a rainbow trout's diet. Weiland and Haywood (1997) looked at the food habits of rainbow trout in Lake Taneycomo. I recalculated their data to a form which would be more comparable to mine. The %IRI for all chironomids was 66.4, from March 1991-November 1992. The second most important food item were cladocerans with a %IRI of 21. Much like at site 3 in Lake Ogallala, while other food resources were used, the chironomids remained the most important taxa for the time period as a whole. The importance of chironomids is much higher at site 3 in Lake Ogallala than in Lake Taneycomo. Unlike Lake Taneycomo, the second most important food resource was not zooplankton but a macroinvertebrate. This may be due to the fact that the rainbow trout in Lake Ogallala have no access to zooplankton as a food source.

A study was done by Hubert et al. (1994) on the diet of rainbow trout in Lake DeSmet, Wyoming, suggested that the primary food source for the rainbow trout were cladocerans, because these had the highest numbers found in stomachs during the entire sampling period and they had the highest biomass during all months except May through August. During the summer months, insect larvae, mostly chironomids, had the highest biomass. My study experimental corral runs were only done May through August, so I can not compare my data to the other months of the year, but during 1998 chironomids were second numerically highest in biomass, and in 1999 they were higher in both categories during the summer months. No benthic information was included with this study, but I would postulate that the increased use of insects was due to their increased availability. Lake Ogallala trout feed predominantly on benthic insects, and no zooplankton was ever found in the stomach samples from the experimental corrals.

The above examples indicate that rainbow trout can and will eat benthic macroinvertebrates, as they do in Lake Ogallala, but often they are second or third on the list of important food taxa. Even when they are the most important taxa taken, as in Weiland and Haywood (1997), the diets are usually supplemented with zooplankton.

Overall Conclusions:

For objective 1, three main conclusions were reached. First chironomids were the most abundant taxon in all sites and years. The general trend was for the numbers to increase throughout the summer and then show a slight decline towards the end of the sampling season. Second, the rainbow trout had very little affect on the benthic community. There was no significant differences between numbers of individuals in experimental vs control corrals. Finally, the fish community in the lake was not having a significant affect on the benthic community of the lake in 1999, and at sites 2 and 3 in 1998.

Three overall conclusions were found for objective 2. First the dietary importance to rainbow trout of the major macroinvertebrate taxa varied among study sites in the lake. Second there was no constant relationship between abundance of macroinvertebrate taxa and their use as food by rainbow trout. Finally I concluded that the rainbow trout were feeding opportunistically.

Management Implications:

It seems clear that zooplankton play a major role in the diet of rainbow trout in most systems. The trout in Lake Ogallala do not have access to this food item. They are surviving on the benthic macroinvertebrates, but may show increased growth and retention if zooplankton were made available to them. The massive amount of alewife present in the lake may never allow the zooplankton to reach a size with which they are useable for the trout. If the alewife were removed from the system, and the zooplankton were allowed to recover, the trout population may experience faster growth and better health. The effective removal of the alewife is an unlikely solution to the problem, so the best management decisions will involve other solutions.

The rainbow trout in Lake Ogallala use the benthic invertebrates as their primary food source. After the renovation in October 1997 the increased number of benthic insects was thought to lead to better retention of the stocked rainbow trout (Barrow, 1998). The renovation also decreased the number of non-game fish, which may be competed with the trout. This reduction allowed for an increase in not only the benthic invertebrates, but also the aquatic macrophytes, allowing for more diversity and density of epiphytic macroinvertebrates. This combination increased the amount of food available to the rainbow trout. In order to sustain the increased growth and retention found in Lake Ogallala after the removal of the competitors, every measure should be taken to maintain or further the development of the food base for these trout. These may have to include such things as continued monitoring of levels of the competitors and the growth and condition of the stocked rainbow trout.

The trout of Lake Ogallala are feeding on benthic macroinvertebrates. Their health and the health of the fishery depends on the ability of the system to provide enough of this resource not only to sustain them but to allow growth of the stocked rainbow trout. Whether or not this is a sustainable fishery without the use of chemical renovation is dependent on how aggressively competitors return. Once these fish (competitors) reach some level, they will lower the abundance of benthic macroinvertebrates to a point where the stocked rainbow trout cannot compete for the limited food resource.

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Table 1. Weekly totals (#/cm^2) of rainbow trout food taxa found in experimental corrals in Lake Ogallala during 1998.

Site 1 1998	6/9/98	6/17/98	6/24/98	7/1/98	7/15/98	7/23/98	7/29/98	8/5/98	8/12/98
Chironomidae	0.05	0.17	0.39	1.21	1.09	2.27	1.14	1.55	1.09
Gastropoda	0.00	0.00	0.00	0.00	0.02	0.02	0.05	0.00	0.00
Oligochaeta	0.35	0.20	0.27	0.10	0.17	0.69	0.62	0.20	0.44
Site 2 1998									
Chironomidae	0.62	0.64	0.91	1.51	2.05	2.57	2.32	1.16	2.20
Gastropoda	0.00	0.00	0.07	0.00	0.00	0.00	0.05	0.07	0.10
Oligochaeta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3 1998									
Chironomidae	0.12	0.62	0.72	1.55	1.04	2.30	3.63	2.79	3.73
Gastropoda	0.54	0.39	0.05	0.07	0.02	0.17	0.07	0.20	0.12
Oligochaeta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. Weekly totals (#/cm^2) of rainbow trout food taxa found in experimental corrals in Lake Ogallala during 1999.

Site 1 1999	6/2/99	6/9/99	6/16/99	6/23/99	6/30/99	7/7/99	7/14/99	7/28/99	8/4/99	8/11/99	8/18/99
Chironomidae	0.02	0.44	0.84	0.47	0.54	0.57	0.44	1.55	0.12	0.27	0.15
Gastropoda	0.00	0.00	0.10	0.02	0.00	0.05	0.00	0.05	0.32	1.18	0.05
Oligochaeta	1.11	1.28	0.17	0.32	0.25	0.20	0.39	0.30	0.37	0.15	0.37
Site 2 1999											
Chironomidae	1.26	1.63	2.32	1.28	1.68	0.44	2.64	0.47	0.12	0.12	0.00
Gastropoda	0.00	0.00	0.00	0.02	0.00	0.02	0.02	1.01	0.37	0.62	0.00
Oligochaeta	0.20	0.12	0.30	0.20	0.05	0.10	0.27	0.39	0.15	0.05	0.00
Site 3 1999											
Chironomidae	0.64	1.06	1.28	1.36	1.11	1.33	2.37	2.27	1.90	2.00	1.46
Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.07	0.05	0.05
Oligochaeta	0.22	0.10	0.30	0.00	0.15	0.17	0.12	0.00	0.10	0.12	0.07

Table 3. Number of corixidae collected in core samples in 1998 and core and activity traps in 1999 from Lake Ogallala, NE.

Corixidae 98	6/9/98	6/17/98	6/24/98	7/1/98	7/15/98	7/23/98	7/29/98	8/5/98	8/12/98
Site 1	0	0	0	0	0	9	0	0	1
Site 2	0	0	0	0	0	0	0	0	0
Site 3	0	0	0	0	0	0	0	0	0
Corixidae 99	6/2/99	6/9/99	6/16/99	6/23/99	7/1/99	7/7/99	7/28/99	8/4/99	8/11/99
Site 1	1	0	0	2	0	2	0	80	25
Site 2	0	0	0	0	0	0	0	5	3
Site 3	0	0	0	0	0	0	9	4	16

Table 4. P-values (α=0.05) for corixidae numbers, with and without activity trap sampling from Lake Ogallala during 1999.

	P- value
Site 1	0.232
Site 2	0.165
Site 3	0.109

Table 5. Weekly totals (#/cm^2) of rainbow trout food taxa found in control corrals in Lake Ogallala during 1998.

Site 1 1998	6/9/98	6/24/98	7/8/98	7/22/98	8/5/98	8/19/98	9/19/98	10/3/98
Chironomidae	0.12	0.52	0.67	0.52	0.99	1.65	4.10	2.00
Gastropoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oligochaeta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2 1998								
Chironomidae	0.10	1.01	1.09	2.44	1.68	1.09	0.86	0.42
Gastropoda	0.00	0.05	0.00	0.02	0.10	0.15	0.59	0.20
Oligochaeta	0.00	1.06	0.00	2.07	2.37	2.17	4.22	3.11
Site 3 1998								
Chironomidae	0.00	0.12	3.13	4.22	5.55	5.73	2.76	2.10
Gastropoda	0.00	0.00	0.62	0.25	0.22	0.07	0.64	0.94
Oligochaeta	0.00	0.07	0.69	0.89	0.72	0.62	0.54	0.99

Table 6. Weekly totals (#/cm^2) of rainbow trout food taxa found in control corrals in Lake Ogallala during 1999.

Site 1 1999	6/2/99	6/9/99	6/16/99	6/23/99	6/30/99	7/7/99	7/14/99	7/28/99	8/4/99	8/11/99	8/18/99
Chironomidae	0.05	0.10	0.25	0.35	0.79	0.25	0.74	0.07	0.35	0.27	0.15
Gastropoda	0.00	0.02	0.44	0.02	0.00	0.05	0.00	0.25	0.00	1.18	0.05
Oligochaeta	0.00	0.02	0.44	0.02	0.00	0.05	0.00	0.25	0.00	1.18	0.05
Site 2 1999											
Chironomidae	0.52	1.83	2.39	1.48	1.16	0.25	0.44	0.67	0.99	0.12	0.00
Gastropoda	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.25	0.12	0.62	0.00
Oligochaeta	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.25	0.12	0.62	0.00
Site 3 1999											
Chironomidae	0.00	0.30	0.39	1.01	1.06	1.31	0.94	1.01	1.33	2.00	1.46
Gastropoda	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05
Oligochaeta	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05

Table 7. Chironomidae genera identified from experimental and control corrals and from rainbow trout stomach samples from Lake Ogallala during 1998.

	Site 1			Site 2			Site 3		
Genus	Experimental	Control	Stomach	Experimental	Control	Stomach	Experimental	Control	Stomach
Chironomus	31	16	9	12	15	3	4	4	4
Stictochironomus	14	1	2	0	6	3	40	13	1
Polyedilum	1	0	0	2	2	0	3	1	0
Dicrotendipes	19	3	5	25	6	4	24	10	0
Glyptotendipes	7	0	0	3	1	0	0	0	0

Table 8. Chironomidae genera identified from experimental and control corrals and from rainbow trout stomach samples from Lake Ogallala during 1999.

	Site 1			Site 2			Site 3		
Genera	Experimental	Control	Stomach	Experimental	Control	Stomach	Experimental	Control	Stomach
Chironomus	16	8	4	0	0	0	0	0	0
Cryptochironomus	2	2	0	9	11	2	22	6	0
Polyedilum	3	0	0	0	0	0	0	0	0
Dicrotendipes	12	6	6	46	13	16	39	29	5

Table 9. Genera of chironomidae ranked by abundance from experimental and control corrals and from rainbow trout stomach samples from Lake Ogallala in 1998 and 1999.

Genus	Site 1		Site 2		Site 3		Year Rank	
	1998	1999	1998	1999	1998	1999	1998	1999
Chironomus	1	1	2	-	3	-	1	3
Stictochironomus	3	-	3	-	1	-	3	-
Polyedilum	5	4	-	-	4	-	5	4
Dicrotendipes	2	2	1	1	2	1	2	1
Glyptotendipes	4	-	-	-	5	-	4	-
Cryptochironomus	-	3	-	2	-	2	-	2

Table 10. P-values (α=0.05) for ANOVA comparisons between experimental and control benthos samples.

	Chironomidae Larvae	Chironomidae Pupae	Gastropoda
Site 1 1998	1	1	NA
Site 2 1998	0.920	0.580	0.163
Site 3 1998	0.194	0.335	0.825
Site 1 1999	0.469	0.207	0.172
Site 2 1999	0.171	0.845	0.952
Site 3 1999	0.426	0.329	1

Table 11. P values (α=.05) for ANOVA comparisons between the numbers of chironomidae, gastropoda, and oligochaeta in the lake and in experimental and control corrals, at Lake Ogallala during 1998 and 1999.

	1998						1999					
	Experimental			Control			Experimental			Control		
Taxa	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Chironomid	0.057	0.252	0.067	**0.007**	0.749	0.078	0.773	**0.041**	0.124	0.364	0.901	0.405
Gastropod	-	0.166	0.669	-	0.504	0.092	0.899	0.931	0.669	0.150	0.777	0.626
Oligochaetes	**0.023**	0.062	**0.0007**	0.177	0.210	**0.023**	0.701	**0.008**	0.100	0.255	0.132	0.340

Table 12. Rainbow trout stomach contents from experimental corrals in Lake Ogallala, Nebraska, 1998 and 1999.

	1998 n=69	1999 n=62
Corixidae	1653	308
Chironomidae	1007	843
Gastropoda	52	95

Table 13. P-values (α=0.05) for ANOVA comparisons between %IRI values of rainbow trout food habits among all three sites during 1998 and 1999.

	1998	1999
Corixidae	0.0582	0.0510
Chironomidae	0.258	0.583
Gastropoda	0.218	0.257

Table 14. P-values (α=0.05) for ANOVA comparisons of rainbow trout %IRI values between 1998 and 1999 at all sites in Lake Ogallala.

	Site 1	Site 2	Site3
Corixids	0.891	0.0001	0.784
Chironomid Larvae	0.803	0.162	0.795
Gastropods	0.379	0.0504	0.328

Table 15. r^2 (α=0.05) values for comparisons of food taxon abundance and food taxon importance for %IRI site by year for rainbow trout in Lake Ogallala during 1998 and 1999.

	Corixids r^2	Chironomids r^2	Gastropods r^2
Site 1 1998	0.138	0.00008	0.015
Site 2 1998	0.064	0.005	0.194
Site 3 1998	NA	0.191	NA
Site 1 1999	0.357	0.046	0.037
Site 2 1999	0.289	0.041	0.068
Site 3 1999	0.548	0.228	0.061

Table 16. Habitat, habit, trophic relationship, North American distribution and, ranked abundance for Chironomidae genera found in Lake Ogallala in 1998 and 1999 (Modified from Coffman and Ferrington 1996).

Genus	Habitat	Habit	Trophic Relationships	North American Distribution	Rank In 1998	Rank In 1999
Chironomus	Lentic-littoral and profundal, lotic depositional	Burrowers (tube builders)	Collectors-gathers (few filters), shredders-herbivores (miners).	Widespread	1	3
Cryptochironomus	Lentic-littoral and profundal, lotic depositional	Sprawlers, burrowers	Predators (engulfers of Protozoa, microcrustacea, Chironomidae, and piecrcers of Oligochaeta.	Widespread	NA	2
Dicrotendipes	Lentic-littoral (wide range of microhabitats)	Burrowers	Collectors-gatherers and filterers, scrapers?	Widespread	2	1
Glyptotendipes	Lentic-littoral and profundal, lotic depositional (rarely), (some instar 1 planktonic)	Burrowers (miners and tube builders), clingers (net spinners)	Shredders-herbivores (miners and chewers-filamentous algae),collectors-filterers and gatherers	Widespread	4	NA
Polypedilum	Lentic-vascular hydrophytes (floating zone)	Climbers, clingers	Shredders-herbivores (miners),collectors-gatherers (and filterers?) predators (engulfers)	Widespread	5	4
Stictochironomus	Lotic-depositional (organic sediments)	Burrowers (tube makers)	Collectors-gatherers, shredders-herbivores (miners)	Widespread	3	NA

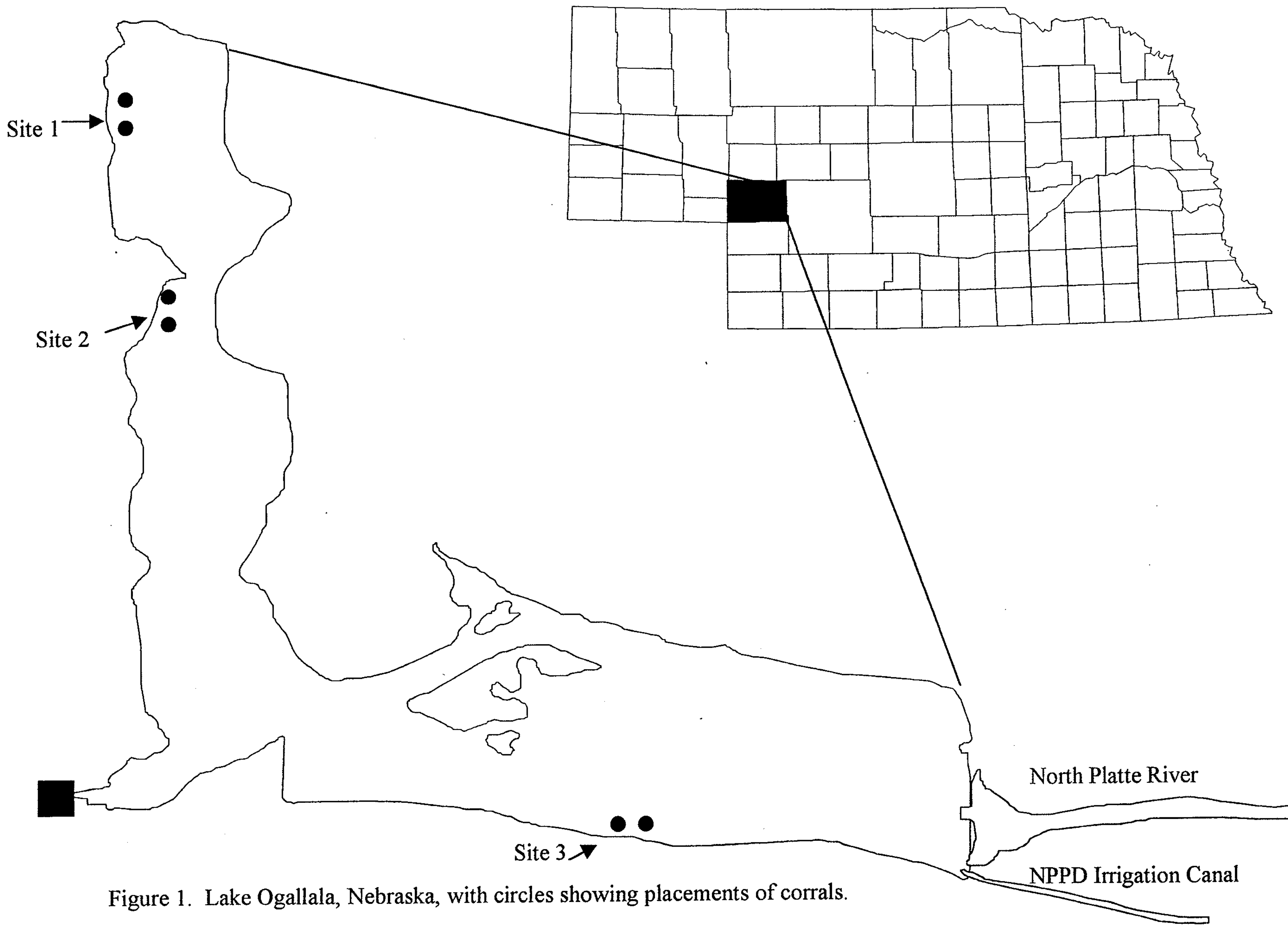

Figure 1. Lake Ogallala, Nebraska, with circles showing placements of corrals.

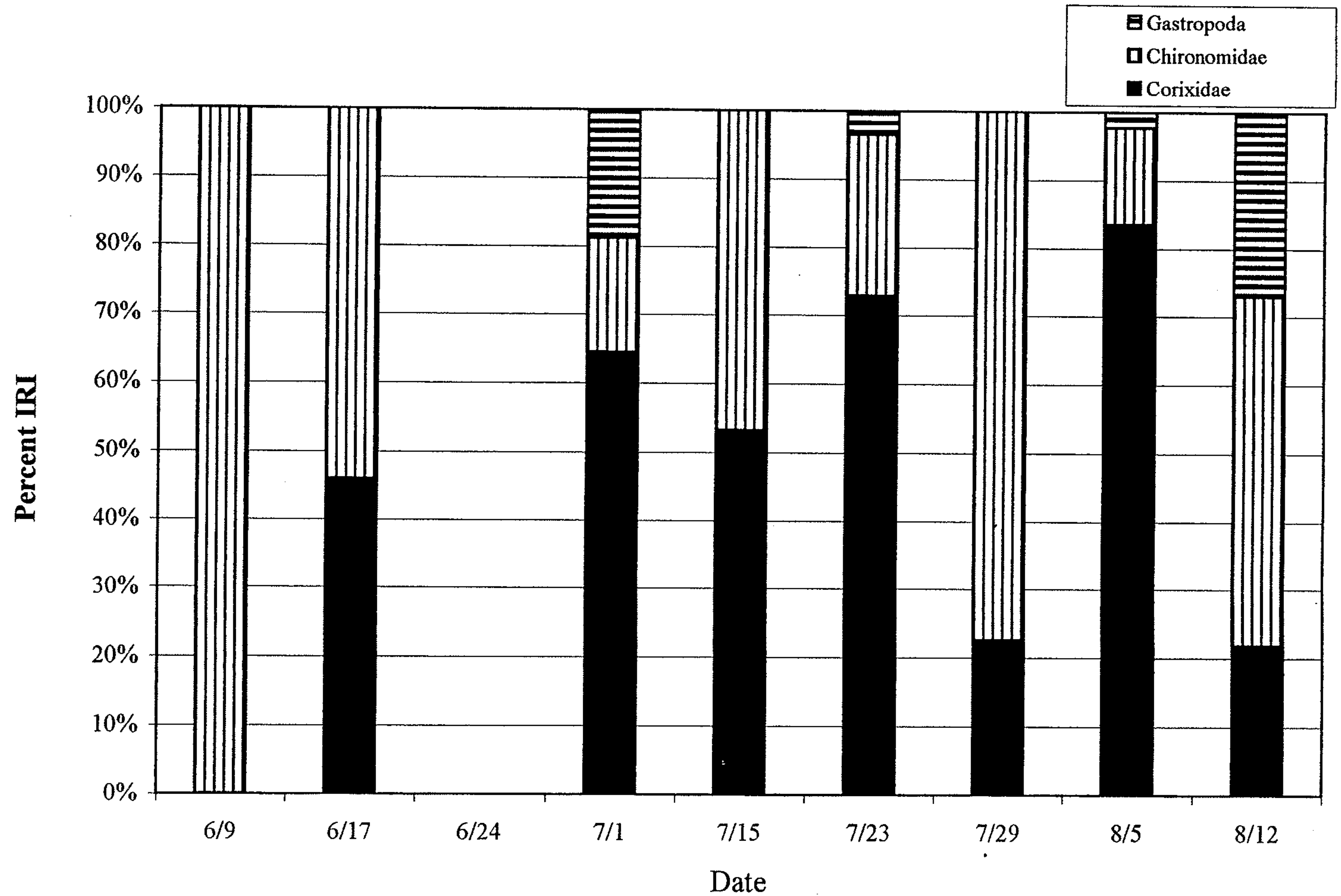

Figure 2. Percent IRI values for major food items of rainbow trout from Lake Ogallala by date for site 1 in 1998.

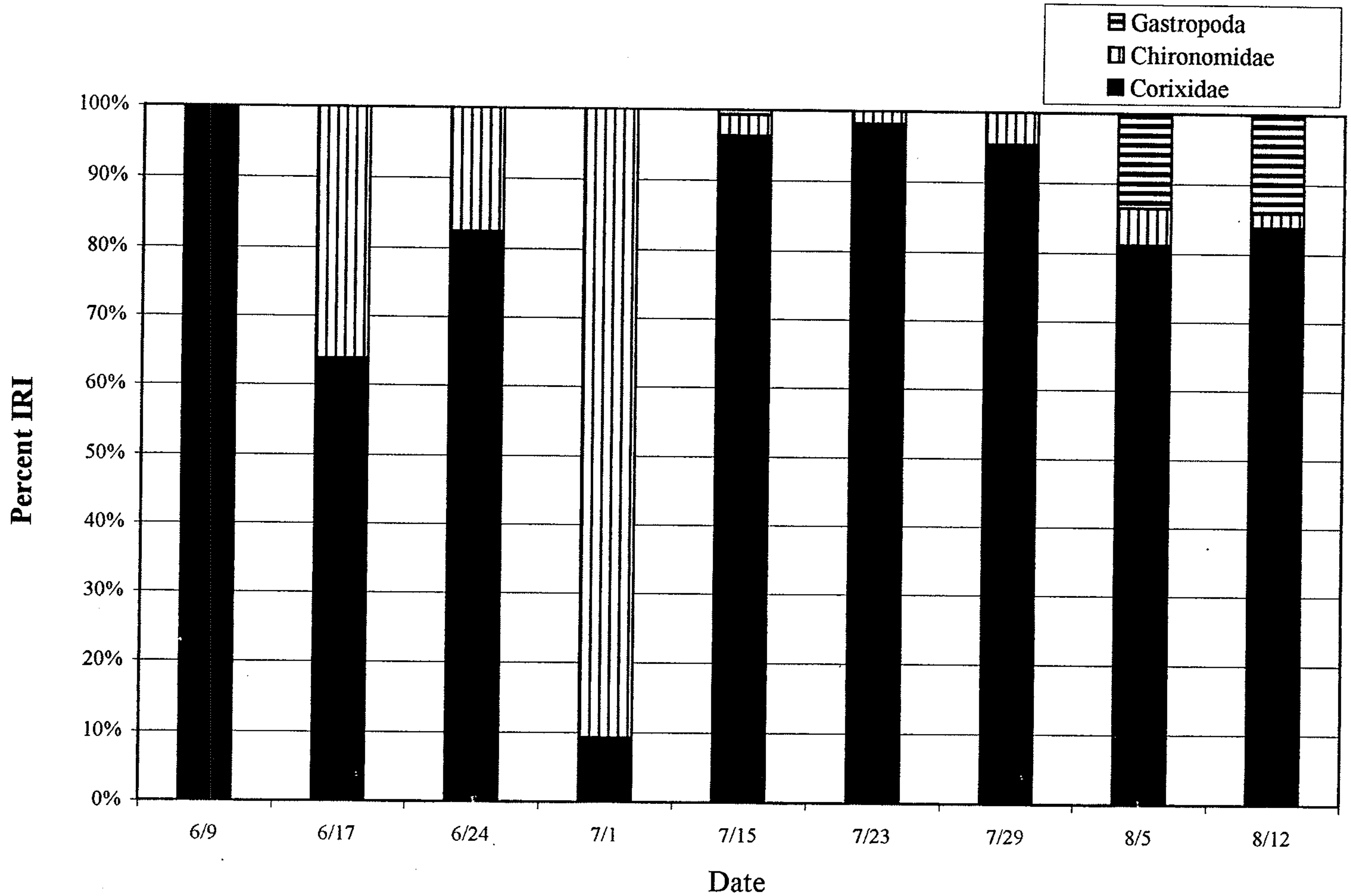

Figure 3. Percent IRI values for major food items of rainbow trout from Lake Ogallala by date for site 2 in 1998.

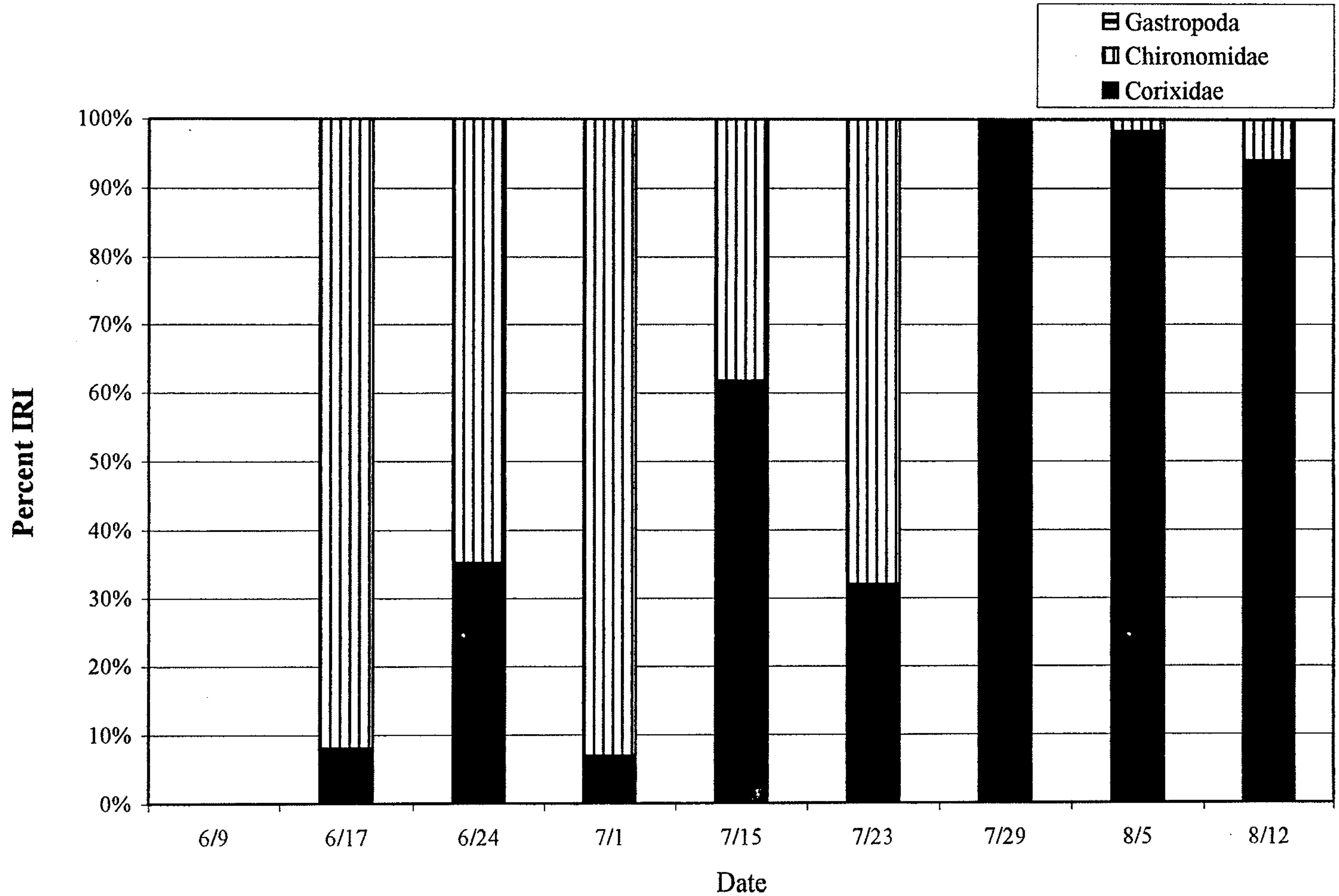

Figure 4. Percent IRI values for major food items of rainbow trout from Lake Ogallala by date for site 3 in 1998.

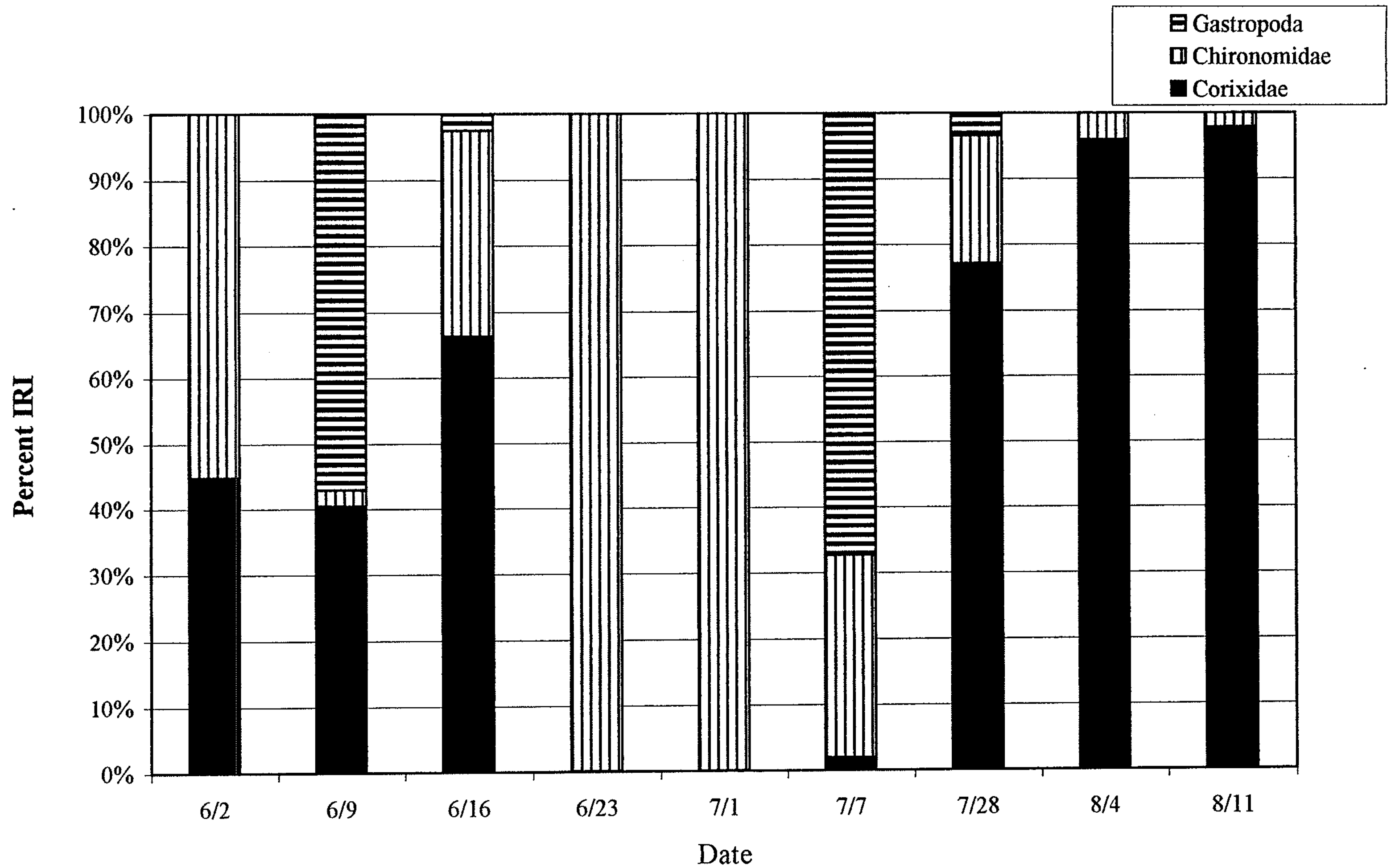

Figure 5. Percent IRI values for major food items of rainbow trout from Lake Ogallala by date for site 1 1999.

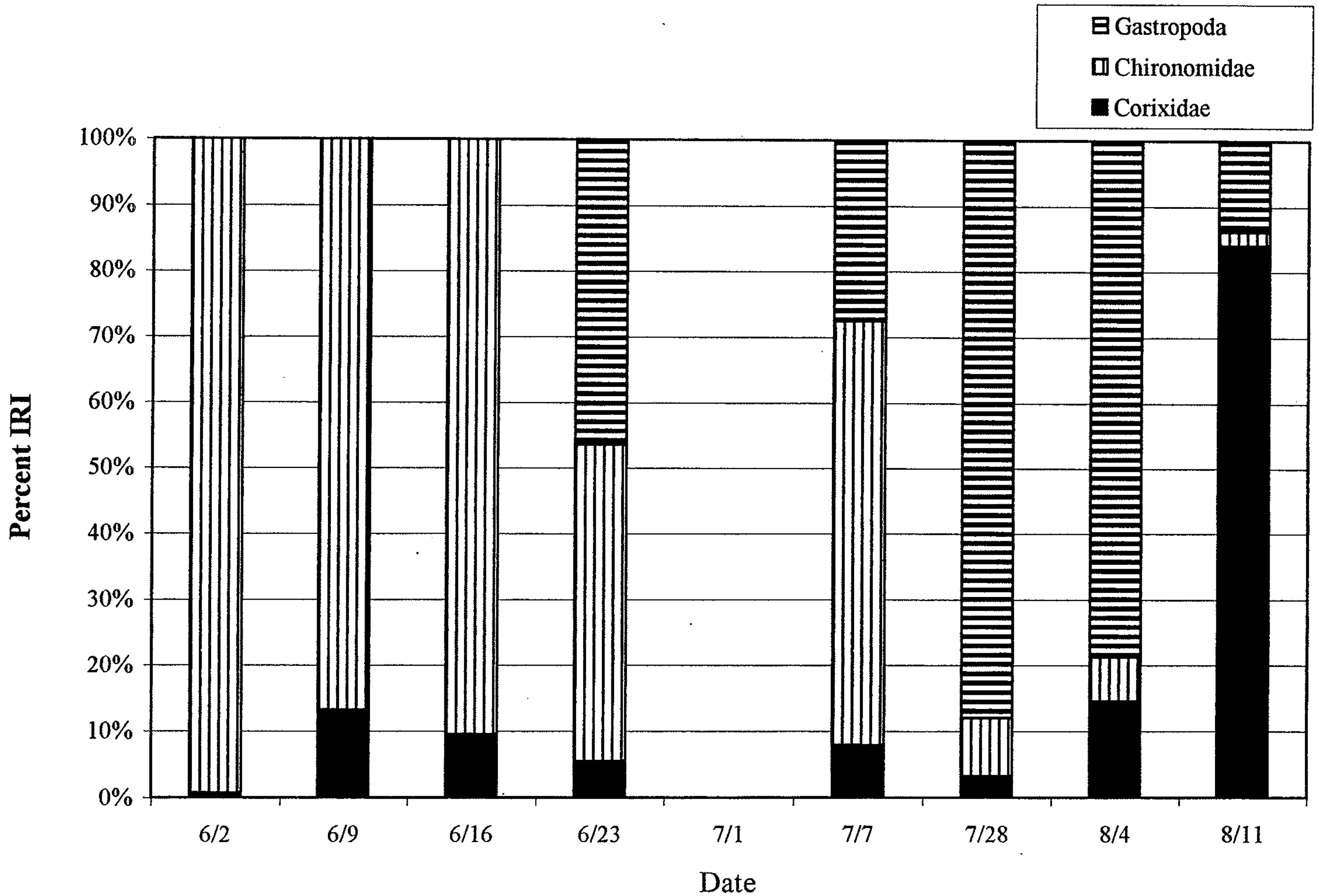

Figure 6. Percent IRI values for major food items of rainbow trout from Lake Ogallala by date for site 2 1999.

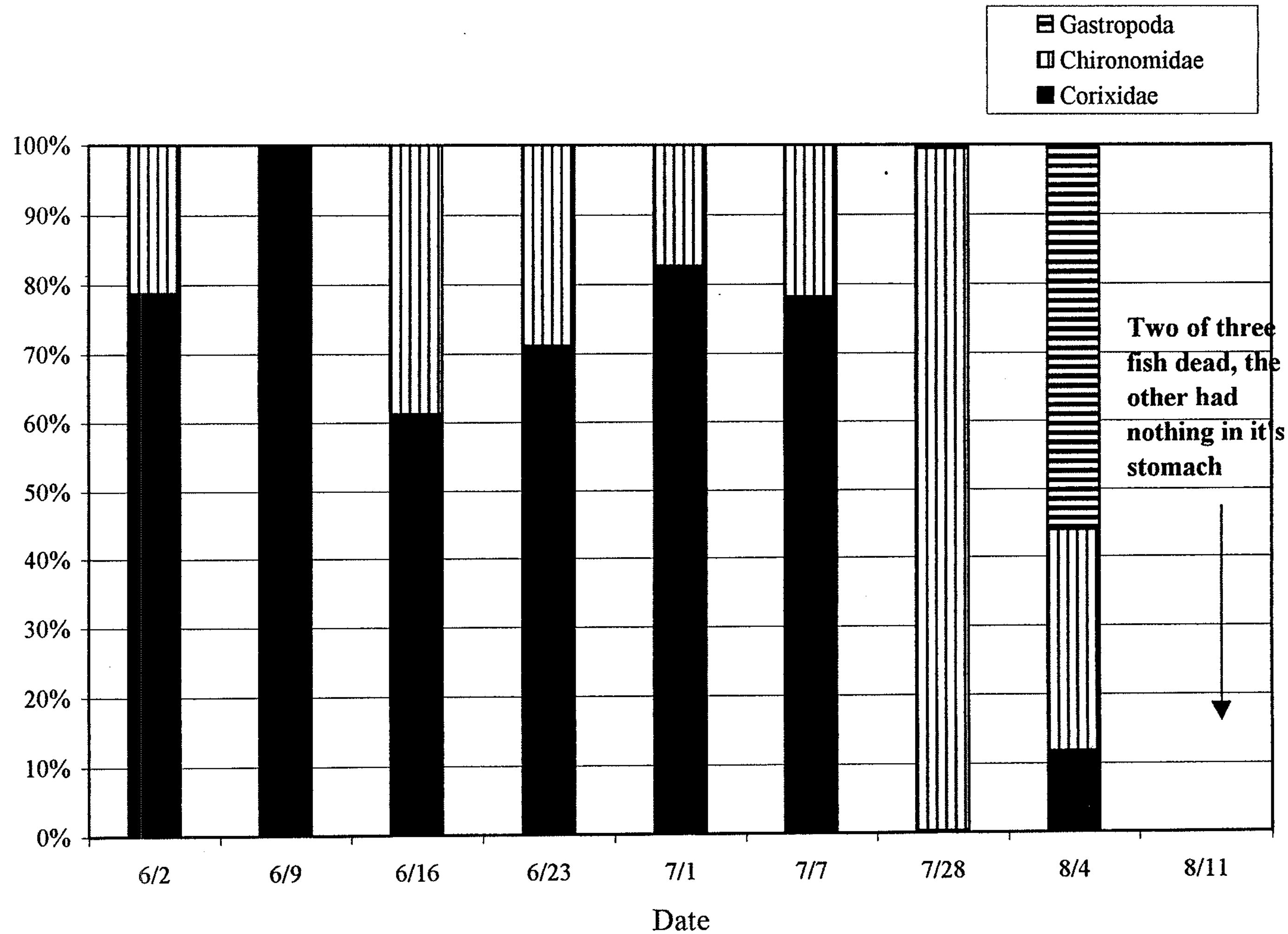

Figure 7.Percent IRI values for major food items of rainbow trout from Lake Ogallala by date for site 3 1999.

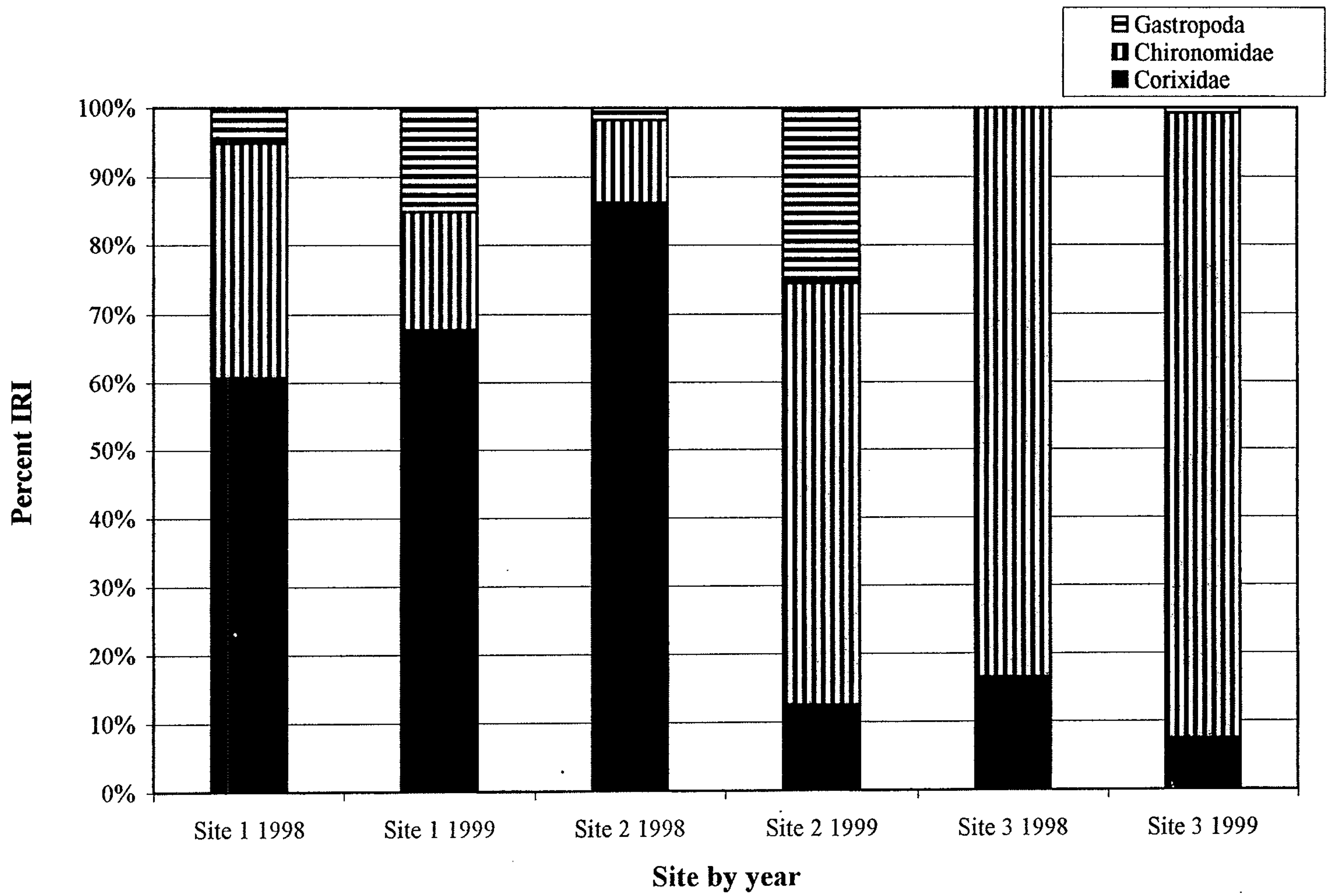

Figure 8. Overall %IRI values for major food items eaten by rainbow trout at all sites in Lake Ogallala during 1998 and 1999.

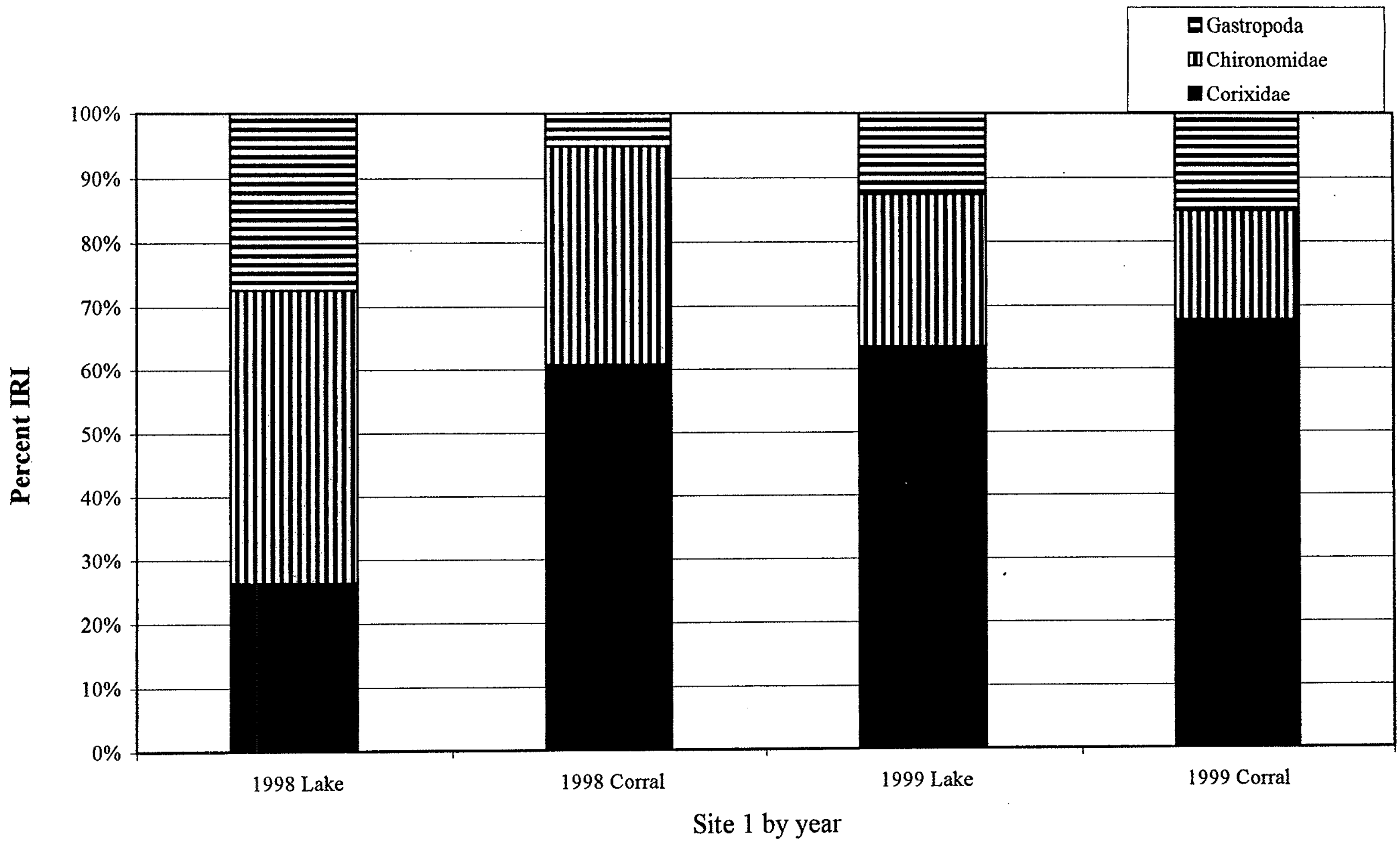

Figure 9. Comparison of lake and corral %IRI values of rainbow trout for site 1 at Lake Ogallala during 1998 and 1999.

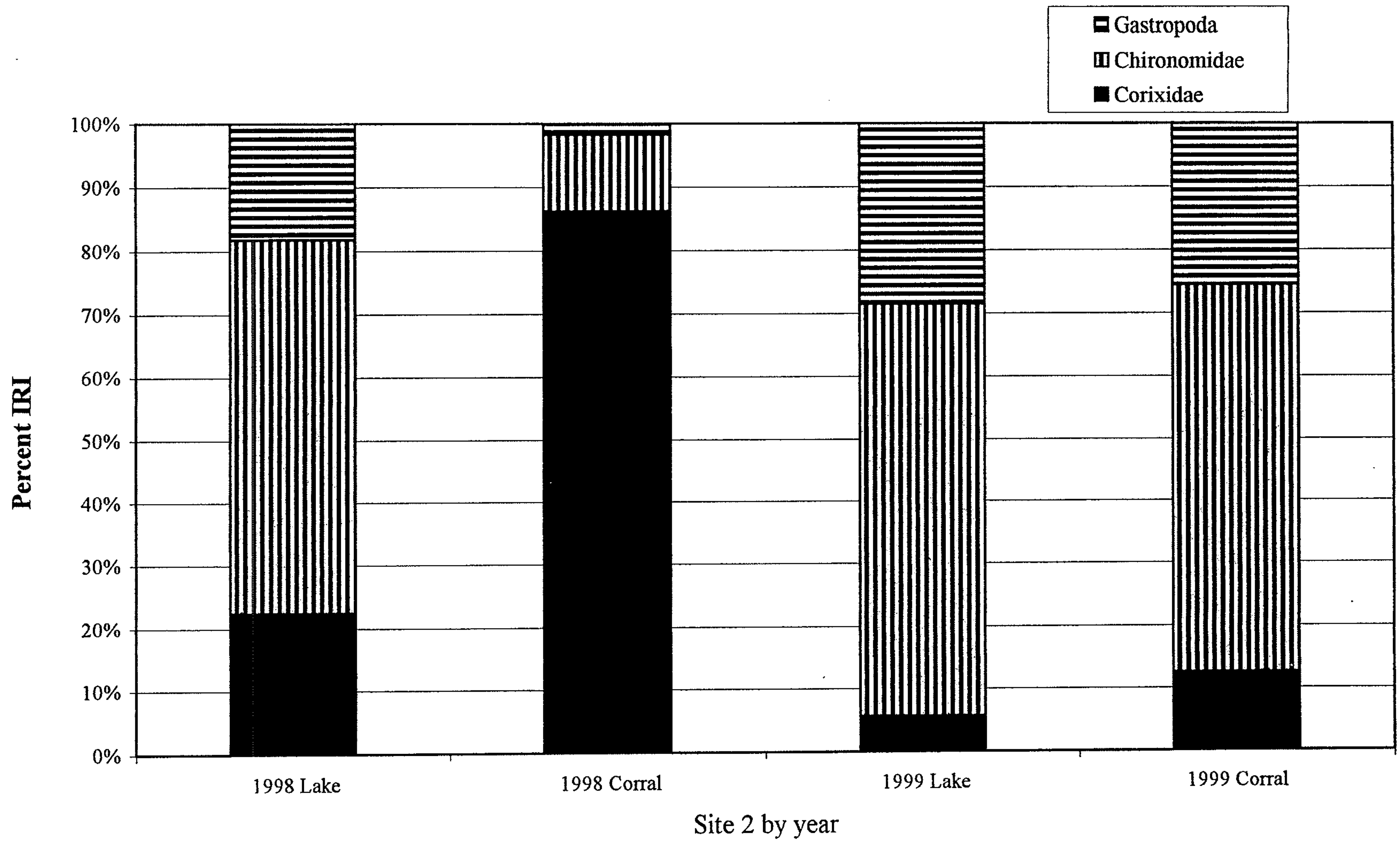

Figure 10. Comparison of lake and corral %IRI values of rainbow trout for site 2 at Lake Ogallala during 1998 and 1999.

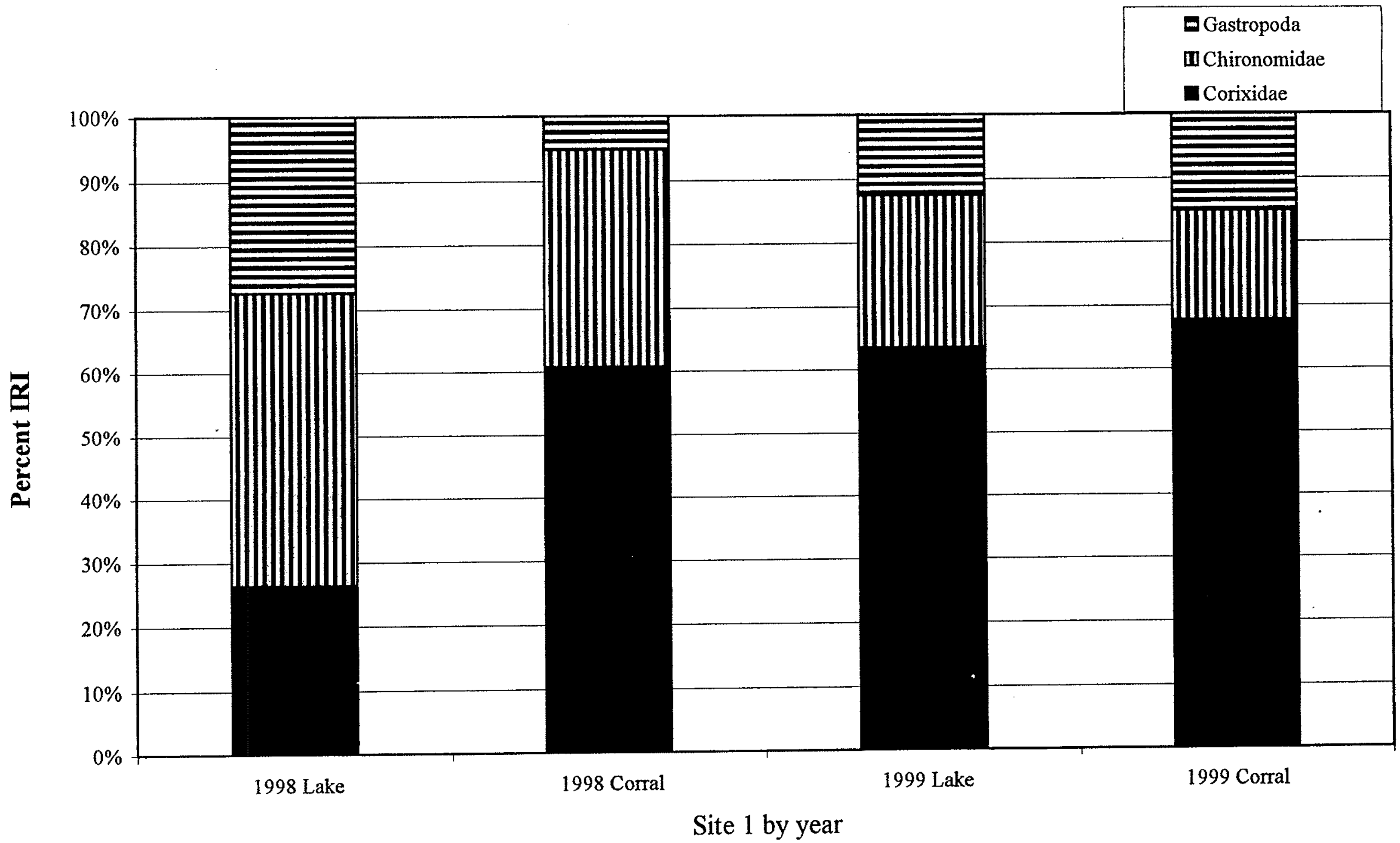

Figure 9. Comparison of lake and corral %IRI values of rainbow trout for site 1 at Lake Ogallala during 1998 and 1999.